

CLAIMS

What is claimed is:

1. A method of providing a phosphorescent coating system on a substrate, said method comprising the steps of:

(A) applying a color-providing composition to the substrate thereby forming an uncured film layer of the color-providing composition; and

(B) applying an at least partially-transparent clearcoat composition wet-on-wet to the uncured film layer of the color-providing composition thereby forming an uncured film layer of the clearcoat composition on the uncured film layer of the color-

10 providing composition;

wherein at least one of the color-providing composition and the clearcoat composition is cross-linkable, and at least one of the color-providing composition and the clearcoat composition comprises phosphorescent pigment to provide the phosphorescent coating system on the substrate.

15 b1 2 A method as set forth in claim 1 wherein the step of (A) applying the color-providing composition is further defined as applying a pigmented basecoat composition to the substrate such that the uncured film layer of the color-providing composition is formed of the pigmented basecoat composition.

20 3. A method as set forth in claim 2 wherein the step of applying the pigmented basecoat composition to the substrate is further defined as applying a

pigmented basecoat composition comprising from 5 to 40 parts by weight of pigment based on 100 parts by weight of the pigmented basecoat composition.

4. A method as set forth in claim 2 wherein the step of applying the pigmented basecoat composition to the substrate is further defined as applying a 5 pigmented basecoat composition comprising at least one pigment selected from the group consisting of organic pigments, inorganic pigments, and combinations thereof.

5. A method as set forth in claim 2 wherein the step of (B) applying the at least partially-transparent clearcoat composition is further defined as applying the clearcoat composition wet-on-wet to the uncured film layer of the pigmented basecoat 10 composition wherein the clearcoat composition comprises the phosphorescent pigment such that exposure of the phosphorescent pigment to an external incident energy source is maximized.

6. A method as set forth in claim 5 wherein the step of applying the clearcoat composition comprising the phosphorescent pigment is further defined as applying a clearcoat composition comprising from 5 to 30 parts by weight of the phosphorescent 15 pigment based on 100 parts by weight of the clearcoat composition.

7. A method as set forth in claim 5 further comprising the step of simultaneously curing the uncured film layers of the pigmented basecoat composition and the clearcoat composition to provide the phosphorescent coating system with the 20 phosphorescent pigment in the clearcoat composition.

8. A method as set forth in claim 7 wherein the step of simultaneously curing the uncured film layers to provide the phosphorescent coating system is further defined as simultaneously curing the uncured film layers to establish a DOI for the phosphorescent coating system of at least 5.5, as defined by ASTM E430-97.

9. A method as set forth in claim 1 wherein the step of (A) applying the color-providing composition is further defined as applying a pigmented basecoat composition to the substrate wherein the pigmented basecoat composition comprises the phosphorescent pigment and the uncured film layer of the color-providing composition is formed of the pigmented basecoat composition comprising the phosphorescent pigment.

10. A method as set forth in claim 9 wherein the step of applying the pigmented basecoat composition to the substrate is further defined as applying a pigmented basecoat composition comprising from 5 to 40 parts by weight of pigment based on 100 parts by weight of the pigmented basecoat composition.

11. A method as set forth in claim 9 wherein the step of applying the pigmented basecoat composition to the substrate is further defined as applying a pigmented basecoat composition comprising from 5 to 30 parts by weight of the phosphorescent pigment based on 100 parts by weight of the pigmented basecoat composition.

12. A method as set forth in claim 9 wherein the step of (B) applying the at least partially-transparent clearcoat composition is further defined as applying the

clearcoat composition wet-on-wet to the uncured film layer of the pigmented basecoat composition to at least partially cover the phosphorescent pigment in the pigmented basecoat composition.

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5 13. A method as set forth in claim 12 further comprising the step of simultaneously curing the uncured film layers of the pigmented basecoat composition, comprising the phosphorescent pigment, and the clearcoat composition to provide the phosphorescent coating system with the phosphorescent pigment in the pigmented basecoat composition.

10 14. A method as set forth in claim 13 wherein the step of simultaneously curing the uncured film layers to provide the phosphorescent coating system is further defined as simultaneously curing the uncured film layers to establish a DOI for the phosphorescent coating system of at least 5.5, as defined by ASTM E430-97.

15 15. A method as set forth in claim 1 wherein the step of (A) applying the color-providing composition is further defined as applying the color-providing composition to a film build suitable for hiding of the substrate.

16. A method as set forth in claim 1 wherein the phosphorescent pigment has an average particle size of from 1 to 50 microns.

17. A method as set forth in claim 1 wherein the phosphorescent pigment has peak excitation level of from 150 to 500 nanometers.

- 18 A method as set forth in claim 1 wherein the phosphorescent pigment has a peak emission level of from 400 to 700 nanometers.
19. A method as set forth in claim 1 wherein the phosphorescent pigment has an afterglow brightness of at least 100 mCd/m<sup>2</sup>.
- 5 20. A method as set forth in claim 1 wherein the phosphorescent pigment is a long persistent phosphorescent pigment having an afterglow extinction time of at least 1000 minutes.
- 10 21. A method as set forth in claim 1 wherein the phosphorescent pigment comprises a matrix of a phosphorescent phosphor of the general formula  $MAl_2O_4:X$  wherein M is selected from the group consisting of calcium, strontium, barium, and combinations thereof, and X is at least one activation element suitable for activating  $MAl_2O_4$ .
- 15 22. A method as set forth in claim 21 wherein the at least one activation element X is europium.
23. A method as set forth in claim 21 wherein the at least one activation element X is selected from the group consisting of europium, lanthanum, cerium, praseodymium, neodymium, samarium, gadolinium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium, tin, bismuth, and combinations thereof.
24. A method as set forth in claim 1 wherein the phosphorescent pigment is  
20  $SrAl_2O_4:Eu$ .

25. A method as set forth in claim 1 wherein the step of (A) applying the color-providing composition is further defined as applying a color-providing composition comprising from 5 to 30 parts by weight of the phosphorescent pigment based on 100 parts by weight of the color-providing composition.

5 26. A method as set forth in claim 1 wherein the step of (B) applying the at least partially-transparent clearcoat composition is further defined as applying an at least partially-transparent clearcoat composition comprising from 5 to 30 parts by weight of the phosphorescent pigment based on 100 parts by weight of the clearcoat composition.

10 27. A method as set forth in claim 1 wherein the step of (A) applying the color-providing composition is further defined as applying a color-providing composition comprising from 5 to 40 parts by weight of pigment based on 100 parts by weight of the color-providing composition.

15 28. A method as set forth in claim 1 wherein;  
the step of (A) applying the color-providing composition is further defined as spray applying the color-providing composition, and  
the step of (B) applying the at least partially-transparent clearcoat composition is further defined as spray applying the at least partially-transparent clearcoat composition.

20 29. A method as set forth in claim 1 wherein the step of (A) applying the color-providing composition to the substrate is further defined as applying the color-providing composition to an automotive body panel.

30. A method as set forth in claim 1 further comprising the step of simultaneously curing the uncured film layers of the color-providing composition and the clearcoat composition such that at least one of the color-providing composition and the clearcoat composition cross-links to provide the phosphorescent coating system.

5 31. A method as set forth in claim 30 wherein the step of simultaneously curing the uncured film layers to provide the phosphorescent coating system is further defined as simultaneously curing the uncured film layers to establish a DOI for the phosphorescent coating system of at least 5.5, as defined by ASTM E430-97.

10 32. A method as set forth in claim 1 further comprising the step of incorporating the phosphorescent pigment into at least one of the color-providing composition and the clearcoat composition prior to the step of (B) applying the at least partially-transparent clearcoat composition to reduce an average particle size of the phosphorescent pigment and any agglomerates of the phosphorescent pigment to less than 10 microns.

15 33. A method as set forth in claim 32 wherein the step of incorporating the phosphorescent pigment into the clearcoat composition is further defined as high shear mixing the phosphorescent pigment and the clearcoat composition with a cowles blade to reduce the average particle size of the phosphorescent pigment and any agglomerates of the phosphorescent pigment to less than 10 microns.

*JFF* 34. A method as set forth in claim 32 wherein the step of incorporating the phosphorescent pigment into the clearcoat composition is further defined as grinding the phosphorescent pigment and the clearcoat composition with grinding media selected from the group consisting of soft grinding media, hard grinding media, and combinations thereof to reduce the average particle size of the phosphorescent pigment and any agglomerates of the phosphorescent pigment to less than 10 microns.

*b1 b2* 35. A method as set forth in claim 32 further comprising the step of simultaneously curing the uncured film layers of the color-providing composition and the clearcoat composition to establish a DOI for the phosphorescent coating system of at least 5.5, as defined by ASTM E430-97.

36. A method as set forth in claim 1 wherein the step of (A) applying the color providing composition is further defined as applying a color-providing composition comprising retroreflective microspheres.

37. A method as set forth in claim 1 wherein the step of (B) applying the at least partially-transparent clearcoat composition is further defined as applying a clearcoat composition comprising retroreflective microspheres.

38. A phosphorescent coating system comprising:

a substrate;

a color-providing film layer formed from a color-providing composition applied to said substrate; and

5 an at least partially-transparent clearcoat film layer formed from an at least partially-transparent clearcoat composition applied wet-on-wet to said color-providing composition as said color-providing composition is uncured;

wherein at least one of said color-providing composition and said clearcoat composition is cross-linkable, and at least one of said color-providing composition and

10 said clearcoat composition comprises phosphorescent pigment.

39. A phosphorescent coating system as set forth in claim 38 wherein said color-providing film layer is further defined as a pigmented basecoat film layer formed from a pigmented basecoat composition applied to said substrate.

40. A phosphorescent coating system as set forth in claim 39 wherein said 15 pigmented basecoat composition comprises from 5 to 40 parts by weight of pigment based on 100 parts by weight of said pigmented basecoat composition.

41. A phosphorescent coating system as set forth in claim 39 wherein said pigmented basecoat composition comprises at least one pigment selected from the group consisting of organic pigments, inorganic pigments, and combinations thereof.

42. A phosphorescent coating system as set forth in claim 39 wherein said clearcoat composition is applied wet-on-wet to said pigmented basecoat composition as said pigmented basecoat composition is uncured and said clearcoat composition comprises said phosphorescent pigment such that exposure of said phosphorescent pigment to an external incident energy source is maximized.

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43. A phosphorescent coating system as set forth in claim 42 wherein said clearcoat composition comprises from 5 to 30 parts by weight of said phosphorescent pigment based on 100 parts by weight of said clearcoat composition.

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44. A phosphorescent coating system as set forth in claim 42 wherein said pigmented basecoat composition and said clearcoat composition are simultaneously cured to form said pigmented basecoat film layer and said clearcoat film layer, respectively.

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45. A phosphorescent coating system as set forth in claim 44 having a DOI of at least 5.5, as defined by ASTM E430-97.

46. A phosphorescent coating system as set forth in claim 38 wherein said color-providing film layer is further defined as a pigmented basecoat film layer formed from a pigmented basecoat composition comprising said phosphorescent pigment and being applied to said substrate.

47. A phosphorescent coating system as set forth in claim 46 wherein said pigmented basecoat composition comprises from 5 to 40 parts by weight of pigment based on 100 parts by weight of said pigmented basecoat composition.

48. A phosphorescent coating system as set forth in claim 46 wherein said pigmented basecoat composition comprises from 5 to 30 parts by weight of said phosphorescent pigment based on 100 parts by weight of said pigmented basecoat composition.

49. A phosphorescent coating system as set forth in claim 46 wherein said clearcoat composition is applied wet-on-wet to said pigmented basecoat composition to at least partially cover said phosphorescent pigment in said pigmented basecoat composition.

50. A phosphorescent coating system as set forth in claim 49 wherein said pigmented basecoat composition and said clearcoat composition are simultaneously cured to form said pigmented basecoat film layer and said clearcoat film layer, respectively.

51. A phosphorescent coating system as set forth in claim 50 having a DOI of at least 5.5, as defined by ASTM E430-97.

52. A phosphorescent coating system as set forth in claim 38 wherein said phosphorescent pigment has an average particle size of from 1 to 50 microns.

53. A phosphorescent coating system as set forth in claim 38 wherein said phosphorescent pigment has peak excitation level of from 150 to 500 nanometers.

54. A phosphorescent coating system as set forth in claim 38 wherein said phosphorescent pigment has a peak emission level of from 400 to 700 nanometers.

5 55. A phosphorescent coating system as set forth in claim 38 wherein said phosphorescent pigment has an afterglow brightness of at least 100 mCd/m<sup>2</sup>.

56. A phosphorescent coating system as set forth in claim 38 wherein said phosphorescent pigment is a long persistent phosphorescent pigment having an afterglow extinction time of at least 1000 minutes.

10 57. A phosphorescent coating system as set forth in claim 38 wherein said phosphorescent pigment comprises a phosphorescent phosphor matrix of the general formula MAl<sub>2</sub>O<sub>4</sub>:X wherein M is selected from the group consisting of calcium, strontium, barium, and combinations thereof, and X is at least one activation element suitable for activating MAl<sub>2</sub>O<sub>4</sub>.

15 58. A phosphorescent coating system as set forth in claim 57 wherein said at least one activation element X suitable for activating MAl<sub>2</sub>O<sub>4</sub> is europium.

59. A phosphorescent coating system as set forth in claim 57 wherein said at least one activation element X suitable for activating MAl<sub>2</sub>O<sub>4</sub> is selected from the group consisting of europium, lanthanum, cerium, praseodymium, neodymium, samarium,

gadolinium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium, tin, bismuth, and combinations thereof.

60. A phosphorescent coating system as set forth in claim 38 wherein said phosphorescent pigment is  $\text{SrAl}_2\text{O}_4:\text{Eu}$ .

5 61. A phosphorescent coating system as set forth in claim 38 wherein said color-providing composition comprises from 5 to 30 parts by weight of said phosphorescent pigment based on 100 parts by weight of said color-providing composition.

10 62. A phosphorescent coating system as set forth in claim 38 wherein said clearcoat composition comprises from 5 to 30 parts by weight of said phosphorescent pigment based on 100 parts by weight of said clearcoat composition.

15 63. A phosphorescent coating system as set forth in claim 38 wherein said color-providing composition comprises from 5 to 40 parts by weight of pigment based on 100 parts by weight of said color-providing composition.

64. A phosphorescent coating system as set forth in claim 38 wherein said color-providing composition is spray applied to said substrate, and said clearcoat composition is spray applied wet-on-wet to said color-providing composition.

65. A phosphorescent coating system as set forth in claim 38 wherein said substrate is an automotive body panel.

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66. A phosphorescent coating system as set forth in claim 38 wherein said color-providing composition and said clearcoat composition are simultaneously cured to form said color-providing film layer and said clearcoat film layer, respectively, wherein at least one of said color-providing composition and said clearcoat composition cross-links as a result of the cure.

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67. A phosphorescent coating system as set forth in claim 66 having a DOI of at least 5.5, as defined by ASTM E430-97.

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68. A phosphorescent coating system as set forth in claim 66 wherein said phosphorescent pigment has an average particle size of from 1 to 10 microns.

69. A phosphorescent coating system as set forth in claim 68 having a DOI of at least 5.5, as defined by ASTM E430-97.

70. A phosphorescent coating system as set forth in claim 38 wherein at least one of said color-providing composition and said clearcoat composition comprises retroreflective microspheres.